PROPOSAL OF A DESIGN CODE FOR SEISMIC ISOLATION OF BUILDINGS IN COLOMBIA

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ABSTRACT

The current seismic design Colombian code (NSR-10) indicates that isolated buildings shall be designed according to USA documents (mainly ASCE 7). Such regulations are fitted to the particular US conditions, not being completely applicable to foreign countries. Therefore, using unreflexively foreign regulations in Colombia might generate technical inconsistencies and economic overruns, thus impairing the promotion of seismic isolation. Moreover, apparently, the last two versions of ASCE 7 (2010 and 2016) differ significantly, although the final results are rather similar. On the other side, the Damping Modification Factors for the US cannot be considered in other countries, given that are strongly dependent on the local seismicity. Finally, the US regulations are apparently oriented to essential buildings, being excessively demanding for ordinary use; conversely, in Colombia, base isolation might be also useful for non-essential constructions. Given the above considerations, a draft proposal of a Colombian design code is under development. This work discusses and compares the most recent two versions of the American regulation ASCE 7 (2010 and 2016), identifies disagreements with the Colombian (NSR-10) regulation, and proposes criteria for analysis and design of buildings with seismic isolation in Colombia.

Keywords: Base isolation; buildings; design code; Colombia; Damping Modification Factor

1. INTRODUCTION

The seismic (base) isolation of buildings consists of incorporating, between the foundation (substructure) and the main structure (superstructure), a number of devices (isolator units) that are highly flexible in both horizontal directions, but are rigid and resistant in vertical direction [Molinares 2011]. The objective is to uncouple partially the structure from the foundation soil in order to reduce the seismic demand in terms of ground-transmitted force and, thus, to mitigate the damage in the building. This effect is mainly achieved through the ensuing large elongation in the building fundamental period; furthermore, since the building motion is basically rigid-body (i.e. most of the deformation is concentrated in the isolation layer while the superstructure does not relevant drift), it is feasible to add additional damping to further reduce the seismic forces. In other words, the incorporation of base isolation is equivalent to adding a new story (ground level); therefore, a new eigenmode arises. This mode is characterized by having long period (thus becoming the first one), holding an extremely high participation factor, and being shaped almost rigid-body (i.e. without relevant drift in the superstructure.

Figure 1 displays a building with base isolation. Figure 1 shows that the isolators are placed at the ground level (they constitute the isolation layer) and that a gap must be left around the building to allow relative movements with respect to the foundation.

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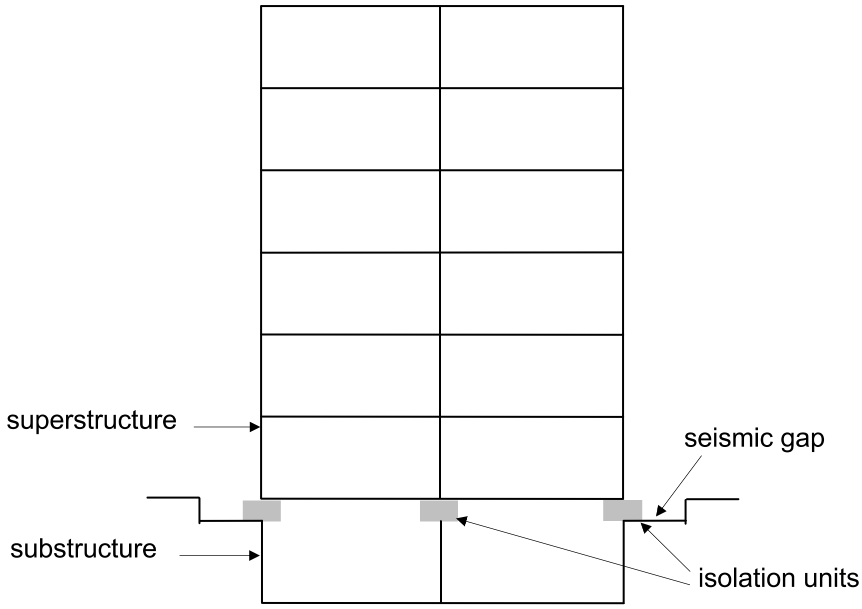

Figure 1. Building with seismic (base) isolation

Nowadays, base isolation is a well consolidated technique, having been incorporated into the most relevant worldwide design codes. The works [Piscal A., López Almansa 2017c; Piscal A. 2018c] present a comparison between the major regulations. Moreover, actual buildings with base isolation have performed satisfactorily under severe earthquakes; this has been verified in countries such as Chile [Almazán 2012], Japan [EERI 2012], China [EERI 2013] and USA [Nagarajaiah, Sun 1996], among others.

In Colombia, a growing interest for seismic isolation of hospital buildings has recently arisen [Piscal A., López Almansa 2017a; 2017b]; as a result of this interest, starting 2011, approximately 30 buildings [Mason 2015] have been designed and built using this seismic protection technology. As Colombia does not have any specific regulation for base isolation, the Colombian seismic design code [NSR-10 2010] recommends using American documents such as [FEMA 450 2004; ASCE 7-10 2010; ASCE 7-16 2016]. The main objective of this study is to discuss the applicability of the new document [ASCE 7-16 2016] to Colombia, mainly compared to the previous one [ASCE 7-10 2010], and to propose criteria to be used in a forthcoming base isolation code for Colombia. The references [Piscal A., López Almansa 2018b, 2019a, 2019b] present previous studies regarding this issue.

2. COMPARISON BETWEEN THE PRESCRIPTIONS OF ASCE 7-10 AND ASCE 7-16 FOR ISOLATED BUILDINGS

2.1 General remarks

As announced in the Introduction, this section presents a detailed comparison between the prescriptions of Chapter 17 of the two most recent versions of the American regulation [ASCE 7-10 2010; ASCE 7-16 2016]. There are important changes between both documents [Mayes 2014] that could generate some controversy in their possible application to Colombia. Next subsections contain specific comparisons for the most relevant issues: Components crossing the isolation layer, Expected seismic performance, Design return period for superstructure and substructure, Required classification (ordinary, intermediate, special), Importance, Drift limits, Building irregularities, Redundancy factor, Methodologies for structural analysis and design, Distribution of forces among stories, Variation of isolation devices parameters, Design displacements estimation, and Minimum design forces and displacements.

2.2 Components crossing the isolation layer

[ASCE 7-16 2016] states that the dynamic response of this type of elements (both structural and non-structural) must be rigorously determined to guarantee, wherever necessary, that long-term deformations do not affect their functioning. This need was not specified in [ASCE 7-10 2010].

The affected elements are the supplies (water, gas, electricity, internet, telephony, etc.), evacuations (sewage and rainwater, basically) and the provisional locking system for wind forces. As for the vertical communication elements passing through the isolation layer, only manual ladders are allowed, since elevators and escalators are not able of absorbing without damage the large generated displacements.

2.3 Expected seismic performance

Table 1 describes the required performance for fixed-base (fb) and base-isolated (ba) buildings [ASCE 7-10 2010; ASCE 7-16 2016]. Table 1 refers to buildings with group use IV [NSR-10 2010]; they correspond to essential facilities according to the American documents.

Table 1. Expected performance in [ASCE 7-16 2016] for isolated and fixed-base essential buildings

Performance	**Seismic event**		
	Frequent	**Moderate**	**Strong**
Life safety (neither life losses nor serious injures)	fb, ba	fb, ba	fb, ba
Structural damage (no significant structural damage)	fb, ba	fb, ba	ba
Non-structural damage (neither significant structural nor non-structural damage)	fb, ba	ba	ba

In Table 1, frequent, moderate and strong events correspond to return periods 72, 475 and 2475 years, respectively.

Table 2 presents results similar to those in Table 1, although in a more understandable way.

Table 2 – Expected performance in [ASCE 7-16 2016] for isolated and fixed-base buildings with use group IV

Seism	**Performance level**			
	Operational (FO)	**Immediate Occupancy (IO)**	**Life Safety (LS)**	**Collapse Prevention (CP)**
Frequent				
Moderate				
Strong				

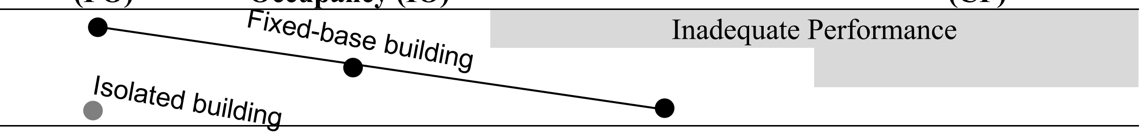

Table 1 and Table 2 show that, according to the American documents, the expected performance level in fixed-base buildings depends on the considered earthquake and the building use; conversely, all the base-isolated buildings must have at least operational performance (FO) level for the strongest earthquake. In fact, [ASCE 7-16 2016] prescribes only the isolated building performance for the strongest earthquake; Table 2 contains the authors interpretation.

2.4 Design return period for superstructure and substructure

One of the major novelties in [ASCE 7-16 2016] is the consideration of a design earthquake with 2475 years return period for superstructure and substructure. It is noteworthy that the previous version [ASCE 7-10 2010] specified, for such purpose, 475 years return period. As evidenced in Table 2, it is expected that the performance of base-isolated buildings (regardless of their use) be better than that of fixed-base essential buildings; therefore, the same design earthquake should be used in both cases.

Table 3 displays the performance of fixed-base buildings with use groups I and IV.

Table 3 – Expected performance in [ASCE 7-16 2016] for fixed-base buildings with use groups I and IV

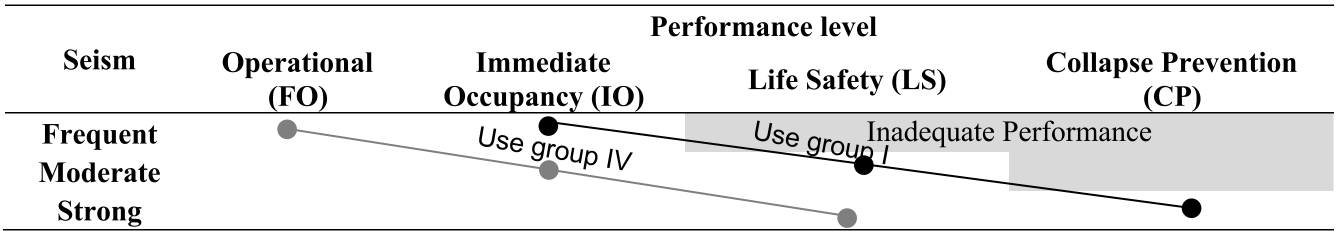

Table 3 shows that the performance of fixed-base buildings depends on the design earthquake and the building use. If the performance level is stated as Life Safety (as specified in most of international regulations), for a building with use group I this performance corresponds to moderate earthquake (T_R = 475 years), while for buildings of use group IV it corresponds to strong earthquake (T_R = 2475 years). In Colombia this last earthquake has been considered by multiplying the design earthquake (475 years) by 1.5 (as stated by ASCE). [ASCE 7-10 2010] considered 475 years return period, but the effect of the strong earthquake was indirectly considered via other safety factors. Thus, both versions of ASCE 7 cannot be mixed.

2.5 Required classification (ordinary, intermediate, special)

[ASCE 7-16 2016] considers that an isolated structure must have the same level of energy dissipation capacity (i.e. ordinary, intermediate or special) than a fixed-base one. Nonetheless, there is an exception, [ASCE 7-16 2016] allows ordinary concentrically braced steel frames (even the connections) in intermediate and high seismic hazard areas. However, a number of conditions must be fulfilled: building height less or equal to 48.4 m, R = 1, and the maximum total displacement (D_{TM}) need to be multiplied by 1.2. This prescription seems to indicate that further versions might allow for designing base-isolated buildings as ordinary ones; this can encourage the use of base isolation.

2.6 Importance

[ASCE 7-16 2016] states that, regardless of the building use, the importance factor for isolated buildings must be always equal to 1. This is equivalent to consider the same return period.

2.7 Drift limits

The drift limit for base-isolated buildings is stated as 1.5% of the floor height (h_{sx}); this bound is stricter than the one for fixed-base buildings and corresponds roughly to Immediate Occupation (IO). This controverts Table 1 and Table 2, where operational performance (FO) is indicated; however, it seems to be more consistent with the level of demand that could be requested to base-isolated buildings.

2.8 Building irregularities

The consideration of irregularities in [ASCE 7-16 2016] and [NSR-10 2010] is different; thus, this issue must be managed with care.

If a given structure is considered as irregular, it conditions the analysis method, and might involve a penalty (either in terms of the seismic design category or the R_0 factor). In [ASCE 7-16 2016] the number of irregularities in base-isolated buildings differs from those in fixed-base buildings, since smaller impact on the structural behavior is expected [De Stefano, Pintucchi 2008; Doudoumis 2005]. Additionally, some irregularities can be even suppressed with an adequate distribution of rigidities in the isolation layer.

The irregularities in seismically isolated buildings according to [ASCE 7-16 2016] are:

- **In height**. 1aA, 1bA and 5aA, 5bA related to variation of rigidity and resistance of the mezzanines, respectively.

- **In plant**. 1bP related to extreme torsional irregularity.

2.9 Redundancy factor

Structural redundancy is synonym of hyperstaticity. In fixed-base buildings, ductility and redundancy provide safety against collapse and excessive damage [Tena et al. 2016]; accordingly, non-redundant structures are penalized. In base-isolated buildings, near elastic behavior is expected; therefore, [ASCE 7-16 2016] states that the redundancy factor applies only for irregular structures.

2.10 Methodologies for structural analysis and design

The strategies for analysis and structural design are basically the same than in fixed-base buildings: Equivalent Lateral Force Analysis (ELF, equivalent static analysis taking a single mode), Response Spectral Analysis (RSA, equivalent static analysis taking several modes), and Response History Analysis (RHA, nonlinear time-history analysis). These strategies can be selected following the recommendations in Table 4.

Table 4 – Analysis and design methods in [ASCE 7-16 2016] for base-isolated buildings

Conditions (site, configuration or isolation)	ELF	RSA	RHA
Soft soil (E or F)	NO	NO	YES
Flexible superstructure	NO	NO	YES
Irregular superstructure	NO	NO	YES
Superstructure with nonlinear behavior	NO	NO	YES
Superstructure with more than 4 stories*, h > 19.8 m*, $T_M > 5$ s	NO	NO	YES
$T_M \leq 3\ T$	NO	YES	YES
$\beta_M > 30\%$ (equivalent damping factor)	NO	NO	YES
Isolation system with high nonlinearity or non-fulfilling 17.4-1(7) [ASCE 7-16 201]	NO	YES	YES

* These bounds can be stricter if there is uplift in the isolation units

In Table 4, h is the building height, T is the fundamental period of the building under fixed-base conditions, and T_M and β_M are the fundamental period and the damping ratio of the isolated building for the maximum displacement, respectively.

Table 4 shows that [ASCE 7-16 2016] reduces the requirements for the ELF method, but, on the contrary, increases the conditions for the RSA. This is because performing multimode analyses when higher modes have only little participation does not make much sense.

2.11 Distribution of forces among stories

[ASCE 7-10 2010] and [ASCE 7-16 2016] consider different force distributions for each level; in certain cases, the distribution specified in the most recent document implies greater demands for the superstructure and the isolator units, given that the resultant is located in a higher position. This new distribution has been adopted after [Ryan, York 2007]. Additionally, this methodology solves the inconsistency in the distribution of [ASCE 7-10 2010] when there are heavy mezzanines located just slightly above the isolation layer.

2.12 Variation of isolation devices parameters

[ASCE 7-10 2010] states the importance of the variation of the devices properties, but does not specify any methodology to consider such issue. [ASCE 7-16 2016] incorporates a series of factors (λ) to estimate the maximum and minimum isolators parameters (basically, stiffness and damping) depending on age, environmental conditions, manufacturing conditions, etc. The range between the minimum and maximum values is highly wide; this is because the provided values must cover many different devices. For that reason, it is indicated that, when more specific information is available (commonly, provided by the manufacturer), it should be used instead.

2.13 Design displacements estimation

In [ASCE 7-10 2010] the design displacements of the isolators are estimated after an effective period that is referred to the minimum properties of the isolators, and an effective damping that correspond to the maximum ones; this approach can be interpreted as inconsistent and providing high displacements. [ASCE 7-16 2016] selects the most critical case between the minimum and maximum properties. This indicates again that both versions of ASCE are not compatible.

2.14 Minimum design forces and displacements

In [ASCE 7-16 2016], when the forces and displacements are estimated by nonlinear dynamic analysis, minimum values referring to ELF apply. Table 5 displays a summary of these conditions.

Table 5 – Minimum design forces and displacements in [ASCE 7-16 2016]

Property	**Substructure**		**Superstructure**	
	ASCE 7-10	**ASCE 7-16**	**ASCE 7-10**	**ASCE 7-16**
Force	90% V_b	90% V_b	80/100% V_s reg./irreg. (RSA) 60/80% V_s reg./irreg. (RHA)	100% V_s (RSA) 17.5.4.3 (RHA)
Displacement	90% D_{TD} 80% D_{TM}	80% D_{TM}	-	-

In Table 5, V_b and V_s represent the design base shear for the substructure (and the isolation layer), and the superstructure, respectively. D_{TD} and D_{TM} are the total displacement for the design and maximum earthquakes, respectively.

3. RELEVANT INCONSISTENCIES BETWEEN ASCE 7 AND NSR-10

This section discusses the differences between the American and Colombian documents that are relevant to seismic isolation. Two relevant issues are identified: the design response spectrum, and the damping modification factor of the spectral ordinates.

3.1 Design spectrum

The design spectra of ASCE and NSR-10 stem from completely different formulations. NSR considers uniform-hazard spectra that correspond to 475 years return period, and are generated after the zero-period spectral ordinate for the bedrock layer (PGA, termed as A_a and A_v). ASCE utilizes instead uniform-risk spectra for 2475 years. However, this difference is not as important, given that ASCE considers two seismicity levels: *M* (maximum, 2475 years) and *D* (design, 475 years); the conversion factor between them is 1.5. Conversely, the most relevant dissimilarity is that the American spectra are generated after the ordinates for short period (0.2 s, S_s) and 1 s (S_1); they are intended to quantify the demand in the constant acceleration (plateau) and constant velocity branches of the spectrum. This strategy requires that actually 0.2 and 1 s belong to such ranges, respectively; certainly, this is not the case in Colombia (and in other Latin-American countries), since in soft soil conditions, frequently 1 s lies in the plateau. For instance, this happens in the microzonations of Bogotá [Decreto 523 2010] and of Cali [Decreto 158 2014], in many areas with soft soil ("Lacustre" 50 through 500 in Bogotá, and "Piedemonte", "Abanico de Meléndez y Lili" and "Llanura Aluvial" in Cali). Noticeably, the first seismically isolated building in Colombia ("Clínica Amiga de Comfandi") is located in the "Abanico de Meléndez y Lili" zone of Cali.

Another relevant distinction is that in the American documents the corner period between the constant velocity and constant displacement branches (T_L) is virtually never used, given that it ranges between 4 and

16 s. Conversely, in Colombia such period is significantly lower, being frequently smaller than the common target periods for seismically isolated buildings; e.g. in cities as Villavicencio, Manizales and Pasto, for soil B, T_L = 2.4 s.

These considerations are relevant to the design codes, given that the Equivalent Lateral Forces method is derived after the above assumptions.

3.2 Damping modification factor

[ASCE 7-10 2010; ASCE 7-16 2016] proposes a spectrum modification factor (B) that depends on the damping ratio (β). Obviously, this factor has been derived after US records, thus not been applicable to other regions. The need of conducting particular studies is evident.

4. DAMPING MODIFICATION FACTOR

4.1 Introductory remarks

As discussed in the Introduction, in base-isolated buildings, the first mode damping is commonly higher than the ordinary reference value (5%), reaching up to 30% (and more). Therefore, to take profit of the beneficial effect of this damping, the spectral ordinates need to be reduced. The American regulations [ASCE 7-10 2010; ASCE 7-16 2016] propose reduction coefficients, but they cannot be applied to countries other than the USA, given that such coefficients have been derived after US registers (subsection 3.2). Particularly, in Latin America (and, even more specifically, in Colombia), soft soil conditions are more frequent and, thus, the registers exhibit different characteristics (subsection 3.1). Given these considerations, studies have been undertaken for Chile [Sáez et al. 2012], Perú [Mendo et al. 2017] and Colombia [Piscal A., López Almansa 2018a]. This section presents a summary of the study for Colombia.

4.2 Description of the study

Given the rather moderate seismicity of Colombia and the limitations and recentness of the seismological network, the available natural severe inputs are scarce. On the other hand, there is not enough information for selecting international records representing the Colombian hazard, such as moment magnitude and hypocentral distance. As well, it is not possible to find records that can be scaled to the design spectra for the full range of periods. Therefore, for each zone and soil type, groups of seven artificial accelerograms fitting the design spectra for 5% damping are generated. The results obtained with these artificial inputs are compared with those for some available historical accelerograms recorded in Colombia. The sensitivity of the calculated modification factors to the soil type, period and seismic zone is investigated, and matching expressions are generated; such equations are intended to be incorporated into the Colombian regulations. These expressions are compared with previous researches and with the prescriptions of major worldwide design codes; a reasonable fit is observed. Finally, a verification example on a hospital building with seismic isolation and located in Cali (Colombia) is presented and discussed. This example further endorses the proposed approach, since their results are satisfactorily compared with those using the historical records that were employed in the seismic microzonation of Cali.

This work considers two modification factors (termed as B_a and B_d) intended to multiply the corresponding 5% damping design spectrum; B_a and B_d are generated from acceleration and displacement (or pseudo-acceleration) response spectra, respectively:

$$B_a(\zeta,T) = \frac{S_a(\zeta,T)}{S_a(0.05,T)} \qquad\qquad B_d(\zeta,T) = \frac{S_d(\zeta,T)}{S_d(0.05,T)} = \frac{PS_a(\zeta,T)}{PS_a(0.05,T)} \tag{1}$$

In equations (1), ζ represents the damping ratio. B_a factor is meant to be used for S_a (acceleration) spectra, thus reporting on non-structural damage. Regarding B_d factor, is meant for both S_d (displacement) and PS_a (pseudo-acceleration) spectra, thus reporting on structural damage.

Colombia is divided in 10 seismic zones (1-10) and five soil types are considered (A-E). Table 6 displays the average proposed expressions in terms of the damping ratio.

Table 6 - Coefficients of the derived expressions for B_d and B_a for damping ratio higher than 5%

Damping ratio	$B_\mathrm{d} = 1 - \frac{a\,T^b}{(T+1)^c}$			$B_\mathrm{a} = d + e\,T$					
				$T \le 0.04$ s		0.04 s < $T \le 0.5$ s		0.5 s < $T \le 4$ s	
	a	*b*	*c*	*d*	*e*	*d*	*e*	*d*	*e*
0.50	1.249	0.3683	0.9200	1.000	– 10.70	0.5873	– 0.3778	0.3184	0.1679
0.45	1.211	0.3683	0.9200	1.000	– 10.27	0.6047	– 0.3880	0.3368	0.1524
0.40	1.166	0.3683	0.9200	1.000	– 9.79	0.6241	– 0.3996	0.3585	0.1368
0.35	1.112	0.3683	0.9200	1.000	– 9.25	0.6461	– 0.3991	0.3849	0.1213
0.30	1.045	0.3683	0.9200	1.000	– 8,61	0.6716	– 0.3954	0.4178	0.1058
0.25	0.9603	0.3683	0.9200	1.000	– 7.84	0.7016	– 0.3846	0.4604	0.0903
0.20	0.8487	0.3683	0.9200	1.000	– 6.90	0.7385	– 0.3597	0.5184	0.0747
0.15	0.6912	0.3683	0.9200	1.000	– 5.65	0.7859	– 0.3027	0.6041	0.0592
0.10	0.4493	0.3683	0.9200	1.000	– 3.86	0.8528	– 0.1788	0.7496	0.0437

5. PROPOSAL FOR THE COLOMBIAN DESIGN CODE FOR ISOLATED BUILDINGS

5.1 Seismic performance

The performance shall increase one level compared to the fixed-base case: LS becomes IO, and CP turns into LS.

5.2 Design input

For the sub and the superstructure, it is proposed to consider the same design input return period than for fixed-base buildings. Regarding the isolation layer, 2475 years is proposed in any case.

5.3 Importance factor

It is proposed to maintain the same importance factor than for fixed-base buildings. The objective is that seismic isolation provides a uniform increment of protection regardless of the building use.

5.4 Damping modification factor

The strategy described in section 3 is considered.

5.5 ELF method

As discussed previously, [ASCE 7-10 2010; ASCE 7-16 2016] assume that 1 s period lies always in the descending branch (constant velocity) of the design spectrum. Conversely, in Colombia soft soil is highly common; thus, in many occasions, such period lies in the constant acceleration branch (plateau). Therefore, equations 17.5-1 and 17.5-3 [ASCE 7-10 2010] and 17.5-1 [ASCE 7-16 2016] cannot be applied to Colombia in all the situations; the following more general expression is proposed instead:

$$S_\mathrm{d} = \frac{g\,S_\mathrm{a}\,T^2}{4\,\pi^2 B} \tag{2}$$

Regarding the response modification factor (R), it is recommended do not exceed 2, as in [ASCE 7-16 2016].

5.6 Design requirements (Ordinary, Intermediate, Special)

[ASCE 7-10 2010; ASCE 7-16 2016] prescribe that an isolated building must have the same structural design level (Ordinary, Intermediate, Special) than a fixed-base one that corresponds to the same seismic design category. This strategy is not considered completely coherent with the philosophy of base isolation, given that a better seismic performance is expected and, thus, less energy dissipation capacity of the superstructure is required. Therefore, the proposal for the Colombian code is that special and intermediate fixed-base buildings convert into intermediate and ordinary isolated ones, respectively; regarding ordinary fixed-base buildings, should become ordinary isolated ones. Noticeably, the recently developed current Chilean code [NCh 2745 2013] contains similar prescriptions.

5.7 Drift limits

In most of building structures, drift angles corresponding to IO (Immediate Occupancy) range between 0.5% and 0.8% [VISION 2000 1995; Aslani 2005; Ghobarah 2004]. Thus, for seismically isolated buildings, a drift limit of 0.7% is proposed.

6. APPLICATION EXAMPLE

This section describes the seismic design of a 4-story RC frame building founded on soil B and located in Bucaramanga (Colombia); this city belongs to a high seismicity zone with $A_a = A_v = 0.25$, $F_a = F_v = 1$. Because of the requirements of the Colombian design code, special frame is considered. The building seismic weight is 2800 kN for both fixed-base and isolated conditions; this involves a certain simplification, given that base isolation might allow designing a lighter superstructure.

The isolation system consists of X0.3R HDRBs (High Damping Rubber Bearings) [Bridgestone 2013]. Table 7 describes the percentages of variation of their mechanical parameters with the temperature, age and production conditions.

Table 7 – Variation of the properties of the Rubber Bearings (%)

Issue	Stiffness	Damping
Production	± 10	∓10
Age	+10	+10
Temperature (20° ± 20°)	+14/–9	+5/–9
Total	**+34/–19**	**+1/–15**

After the variations shown in Table 7, Table 8 displays the selected stiffness, damping and period values. These parameters correspond to 475 years return period.

Table 8 – Selected parameters for the isolation system

Level	Stiffness (kN/mm)	Damping (%)	Period (s)
Minimum	1.314	17	2.90
Nominal	1.546	20	2.70
Maximum	2.072	20.2	2.33

According to the Colombian regulations [NSR-10 2010], two uses are considered: use group I (Risk Category I, the lowest one) and use group IV (Risk Category IV, the highest one, essential facilities). Table 9 displays the design parameters for both uses; R is the response modification factor, I is the importance factor, D_M is the maximum displacement, and V_s is the design base shear.

Table 9 – Design parameters for ordinary / essential buildings				
Parameter	**Fixed-base building**	**Isolated building**		
		ASCE 7-10 2010	**ASCE 7-16 2016**	**Proposed**
R	7 / 7	2 / 2	2 / 2	2 / 2
I	1 / 1.5	1 / 1	1 / 1	1 / 1.5
D_M (m)	- / -	0.155 / 0.155	0.218 / 0.218	0.123 / 0.191
V_s (kN)	250 / 375	161 / 161	173 / 173	124 / 166

Table 9 shows that, for group I buildings, the proposed elastic design base shear is clearly below those in both versions of ASCE 7. Conversely, for group IV buildings, the return period is 2475 years, and, the proposed elastic design base shear lies in between those in the 2010 and 2016 versions of ASCE 7. These considerations seem to indicate that ASCE does not encourage the seismic isolation of non-essential buildings.

7. CONCLUSIONS

This work compares the prescriptions of [ASCE 7-10 2010] and [ASCE 7-16 2016] for buildings with seismic isolation. It is concluded that both documents are quite different, and, thus, their prescriptions cannot be combined. As well, relevant inconsistencies with [NSR-10 2010] and the Colombian situation are found; mainly, the American documents do not discriminate the base isolated buildings based on their importance, they assume that 1 s period lies in the constant velocity branch of the spectrum. Regarding the first issue, the requirements for non-essential buildings might be over-conservative, does not fostering their seismic isolation. On the second issue, some expressions are modified, and a study for the Damping Modification Factor that is specific for Colombia has been conducted.

Given that ASCE 7 cannot be directly applied to Colombia, a draft proposal of seismic regulation for base isolated buildings is presented.

8. ACKNOWLEDGMENTS

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LIST OF ACRONYMS

CP: Collapse Prevention
ELF: Equivalent Lateral Force
FO: Fully Occupational
IO: Immediate Occupancy
LS: Life Safety
RHA: Response History Analysis
RSA: Response Spectrum Analysis